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http://translate.dictionary.com/
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http://www.facstaff.bucknell.edu/rbeard/diction.html

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Translation of German Patent Document No. 19,521,387
Inventor: Roland Gesche et al.
Applicant: Balzers und Leybold Deutschland Holding AG
Priority Date: N/A
Int. Class: H05 H 1/46; H03 H 7/40; G05 B 13/02
Application Date: June 13, 1995
Publication Date: December 19, 1996
Original German Title: Verfahren zum automatischen Abstimmen eines Anpassungsnetzwerks, das zwischen einer elektrischen Energiequelle und einer Last angeordnet ist.

METHOD FOR AUTOMATIC TUNING A MATCHING OR ADAPTOR NETWORK ARRANGED BETWEEN AN ELECTRICAL POWER SOURCE AND AN LOAD

Description

The invention relates to a method as defined in the preamble of Claim 1.

High frequency plasma generation in systems for the application and removal of thin layers has found wide acceptance. In this case, the variable impedance of the plasma must be transformed to the steady load impendence of a 13.56 Mhz high frequency generator and may be 50 Ohm. To accomplish this, matching or adaptor networks are commonly used which are arranged between the high frequency generator and the plasma path.

Such matching or adaptor networks are provided with variable coils and/or capacitors which are adjusted manually in order to do the matching.

Methods for controlling a plasma process are already known in which the change in impedance of a high frequency performance is indicated (US-A-4,207,137). In this case, an impedance recorder is configured as a phase and quantity detector. This recorder comprises inductive current recorders which can only be protected with great difficulty from capacitative couplings. Automatic matching cannot be accomplished by means of the impedance recorder.

In another known matching circuit for supplying high frequency electromagnetic power to a variable impedance, a plurality of tunable capacitors and tunable inductances are provided (US-A-4 679 007). In this case, the inductively operating recorders and phase analysers that are used are afflicted with drawbacks.

An automatic antenna coupler is also known which employs a system in which the real portion of a complex impedance or admittance is measured which is provided by an antenna or a network (US-A-3,913,644). In this case, an inductive current converter is used as measurement recorder.

An finally, a circuit arrangement for automatically tuning a matching network is known in which two electrical values are measured in the

matching network and are supplied to the control unit (DE-A-39 23 662). The control unit employs these values to provide the total of three electrical values and, based on these values, it adjusts the inductance and/or capacitance of the matching network. This means that a high frequency generator is connected by a coaxial line to a matching network, a so-called "matchbox," with the cathode being connected to the output of the matchbox. At the input of the matching network a measurement recorder, for example, a phase-value detector, which generates two signals which contain information about the mismatch of the matchbox. These signals are supplied to the control unit which typically delivers the adjusted values to motor-adjustable capacitors of the matchbox. A drawback in this case is that the characteristic field of the match is a function of the load impedance, but matching the control strategy to the load impedance is not an option. This tends to cause the control to oscillate with some loads or to cause insufficient minimization. Sometimes it is necessary to repeat the adjustment for different loads, and this limits the flexibility. Previous controls have also tended to drift, and this is not always correctable by a new adjustment.

If mismatches occur, automatic tuning cannot find the adjustment range because, on the one hand, the characteristics of the mismatch range are

very complex and cannot be retraced by the controls and, on the other hand, the conventional records for mismatches are not sufficient to deliver sufficiently detailed two-dimensional information in the complex impedance field of the Smith diagram.

An active recorder with high dynamics and an improved control strategy, as known from the above-mentioned DE-A-39 23 662, is an improvement, but it is not a perfect solution, since the requirements on the load impedances constantly increase, especially if large cathodes are involved. Microcomputer-controlled controls cannot solve the problem alone without improved precision recorders.

It is therefore the object of the present invention to provide a stable matching circuit which is not afflicted with the aforementioned drawbacks.

The advantage obtained with the invention is more particularly that it is no longer necessary to employ high precision matching and, therefore, expensive recorders which cover the entire dynamic range. Nor is it necessary to undertake numerically extremely large control simulation which would only increase the uncertainty of the measurements.

An embodiment of the invention is described in greater detail below and illustrated in the drawing in which:

Fig. 1 is a view of a matching circuit for a variable load impedance including the associated control circuit;

Fig. 2 is an arrangement for generating the controlled values from the measured values.

Figure 1 illustrates a high frequency generator 1 which oscillates on a frequency of 13.56 MHz, and a matching network 2 connected to a variable load impedance 3. The matching network 2 is provided with three capacitors 3, 5, 6 in the longitudinal branch, and two parallel oscillating circuits 78 in the transverse branch. These oscillating circuits 7, 8 are made of variable capacitors 9 and 10 and a stationary coil 11 and 12, with the oscillating circuit 8 being connected with one of its connectors to ground 13 and with the other connector between the capacitors 5 and 6, while the other oscillating circuit 7 is also connected to ground, but with the other connector it is connected to the capacitor 4 and 5.

Two different values are picked off the matching circuit 2 and fed to a control unit 14. These two values are the voltage U_E, which is present at the output of the high frequency generator, and the voltage U_1 , which is present at the parallel oscillating circuit 7. The voltages U_E and U_1 are fed by way of capacitative voltage distributors 15, 16, each or which contains two capacitors 17, 18 and 19, 20, to the control unit 14, which outputs control

values x_1 and x_2. These control values x_1 and x_2 are amplified in amplifiers 21, 22 and are transmitted to adjustment motors 23, 24, which make an adjustment in the capacitors 9 and 10. The capacitors 9, 10, in this case, are adjusted in such a way that the matching network 2 always takes in a resistance value Z_{Esoll}, which corresponds to the inside resistance of the high frequency generator. When matching occurs, Z_E must be real and 50 Ohm. This determines the matching requirement for Z_{1soll}, i.e., the resistance value which must occur at U_1 up to 50 Ohm less the impedance of the stationary capacitor 4. Since this is very complex, the total of the two impedances make a statement about the real and imaginary portion of the reflection factor or the input impedance.

What is new, however, is that now the voltage is picked up from the output capacitors 6 and is fed via capacitors 46, 47 and 48, 49 to the control unit as signals $\sim U_1$ and $\sim U_2$.

Figure 2 illustrates the basic operation of the control unit 14 in greater detail. It can be seen that the signals,

$\sim U_E$ and $\sim U_1$

in this case, are each fed to a band pass filter 27, 28. The transmission functions of these filters 27, 28 and the transmission functions of the voltage distributor 15, 16, in this case, are in phase, which can be easily

accomplished by a corresponding adjustment. The output signals of the two band pass filters 27 and 28 are fed into a subtracter 26 to which a rectifier 29 is connected whose output signal is fed to two dividers 30, 31. The output signal of band pass filter 27 is further fed to a rectifier 32 whose output in connected to a second input of the dividers 30. The output signal of the band pass filter 28 also reaches a second input of the divider whose output signal is again fed to two control value generators 34 and 35. A third control value generator 36 only receives the output signal from the divider 30. The output signal of this control value generator 36 is applied to a normal amplifier 37 and an inverting amplifier 38 and from there it is fed to an output 39 or 40. The output signals of the control value generator 34, 35, however, are fed to outputs 40 or 39 via a PID-control unit 41 or 42. Control values x_1, x_2 , which are fed to the adjustment motors 23, 24, are then present at outputs 39, 40, as illustrate din Fig. 1.

The signal $\sim U_A$ is fed via a band pass filter 50 and a rectifier 52 to a divider 54. A further signal $\sim U_2$ is fed via a band pass filter 51 and a rectifier 53 on a further divider 55.

Fuzzy logic is applied to the circuit arrangement in Fig. 1 and Fig. 2. In this case, fuzzy logic is involved which processes the truth values of a statement (linguistic variable) between 0 and 1. The number of the

"degrees of truth" is a function of the concrete realization. Both analogue (continuous) and multiple value digital (quantitized) realizations are available in this case. The most important basic operators of the fuzzy logic are the fuzzy-AND (minimum operator) and the fuzzy OR (maximum operator) und the fuzzy-NOT (negation). Although the minimum operator always forms the minimum of the degrees of truth of a plurality of variables, for example, MIN (0.5; 0.8;0.2) = 0.2. The limiting case in binary logic is AND (0;1) = MIN (0;1) = 0. The maximum operator always forms the maximum degree of truth of a plurality of variables, for example, MAX (0.5; 0.8; 0.2) = 0.8. The limiting case in binary logic is the OR (0;1) = MAX (0;1) = 1. However, for final sequencing or processing fuzzified values (variables), the AND is often not optimal, since in minimum formation it does not take into consideration other points of view that occur at a slightly greater degree of truth and which would result in a certain compensation of the statement. This is why the compensatory AND (gamma operator) was also introduced. Selecting a parameter y ($0< \gamma <1$) allows for an operator to be set continuously from a minimum operator ($\gamma = 0$) to a maximum operator ($\gamma = 1$). The fuzzy negation is simply the complement formation (F' = f-F) of fuzzy variables. The negation of the binary logic is included here too as a limiting case (NOT(0) = 1 = 1-0 = 1 or NOT (1) = 1-1 = 0).

The basic principle of processing this unclear data is product rule IF…THEN. The application of fuzzy logic can result in more optimal system concepts or system solutions, for example, in control technology, since unclear statements often correspond better to the truth than the binary statement "true" (1) or "false" (0).

Three strategies are superimposed in this type of fuzzy logic system:

1. Measurement of the plasma impedance, calculation of the required capacity value, adjustment of the capacitors (reliable in case of mismatch, fast, but not precise);

2. Measurement of the matchbox input impedance, formation of the G' adjustment signals form the deviation in calibration (precise in case of a good match, poor capture behavior in case of a mismatch);

3. Minimization of the generator-Pr indicator (difficult automatically, but required for the calibration.

As a consequence, the control is an uncertain system. First, three independent strategies are formed, which are partially more based on empirical statements and partially on simplified system descriptions. The statements of these strategies must by suitably superimposed. Case differentiation and commutation are out of the question, since this would lead to instabilities and oscillation, because the different strategies may be

completely contradictory. In this case, a fuzzy control system is employed. This allows dependable behavior to be realized if all individual information is unstable but redundancy is available for all. The different strategies are formulated in fuzzy syntax and applied in parallel.

Claims

1. Method for the automatic tuning of a matching network, which is arranged between en electric power source and a load, characterized in that an automatic tuning control unit is used which operates as a fuzz y system.

2. Method as defined in Claim 1, characterize in that the load is a plasma path, that the impedance of this plasma path is measured, the capacity of the capacitor of the matching network is calculated based on the measurement of the plasma impedance and is adjusted correspondingly.

3. Method as defined in Claim 1, characterized in that the input impedance of the matching network is measured and if there is a deviation in the input impedance of a predetermined value, an adjustment signal is determined for the capacitors of the matching network, and the capacitor or capacitors are adjusted correspondingly.

4. Method as defined in Claim 1, characterized in that the wattage of the power source is minimized.

Nummer: DE 195 21 387 A1
Int. Cl.[6]: H 05 H 1/46
Offenlegungstag: 19. Dezember 1996

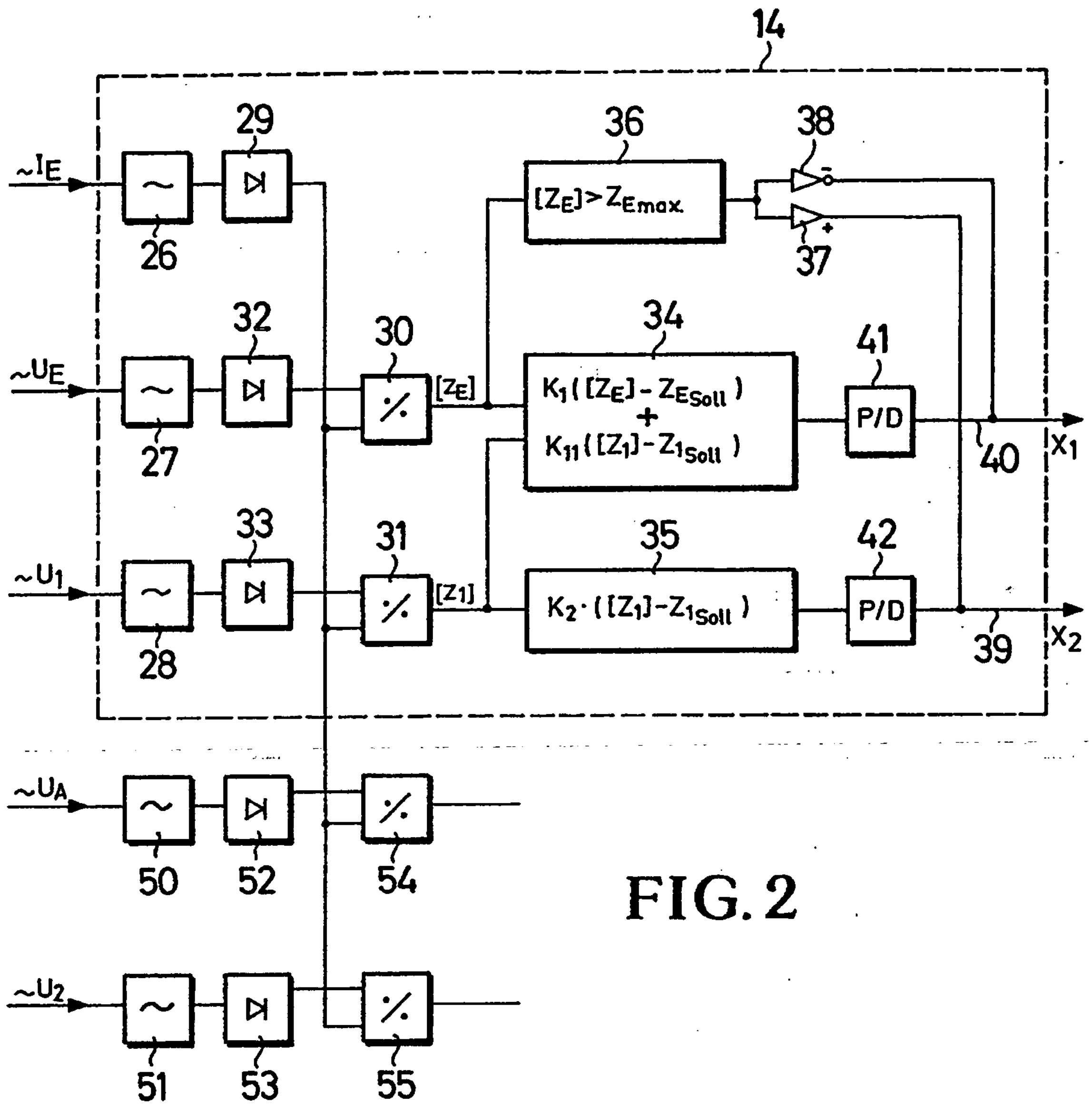

FIG. 2

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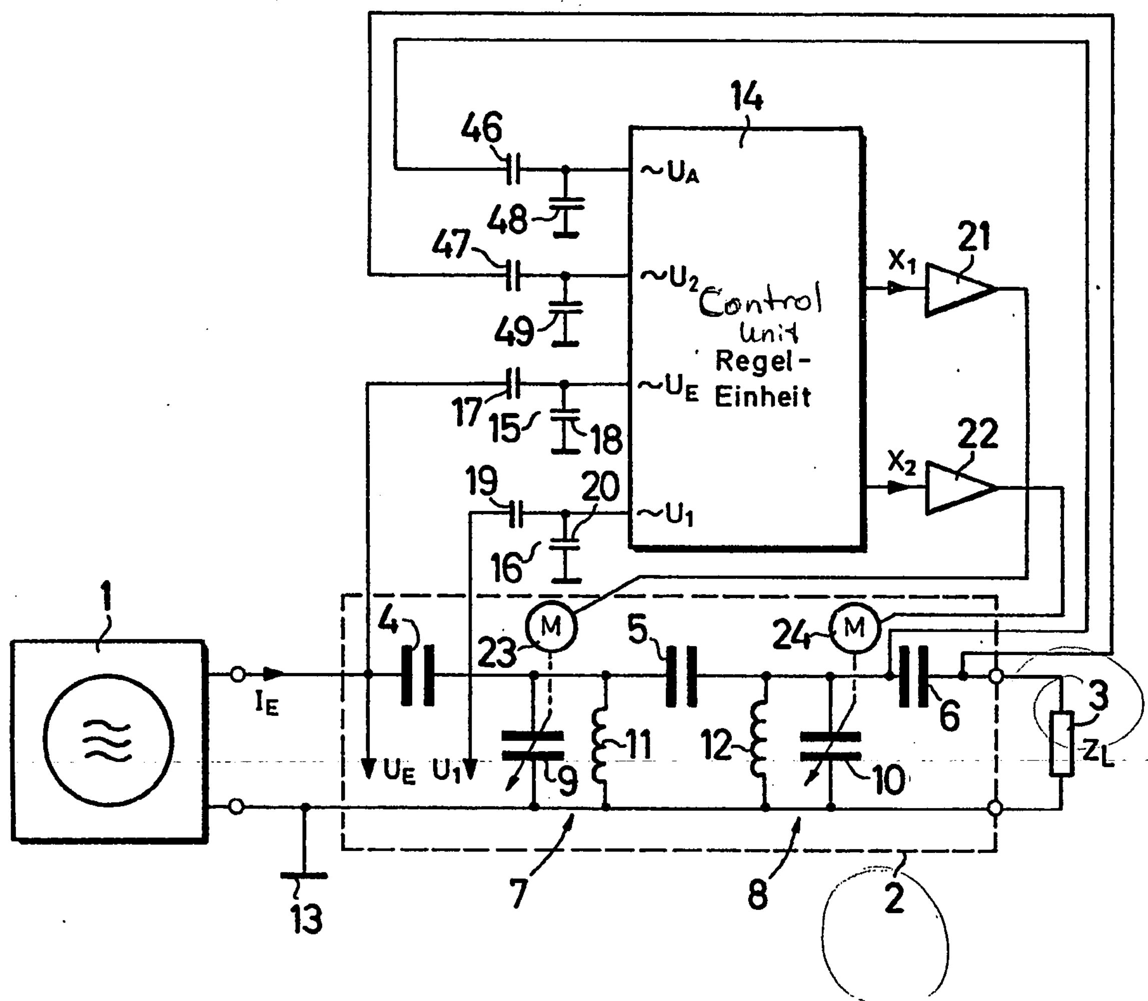

FIG. 1

5. Method as defined in Claims 2 to 4, characterized in that the three methods are superimposed in a fuzzy system.

6. Method as defined in Claims 4, characterized in that subsequent to minimizing of the wattage of the power source, a calibration of the matching network occurs.

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Martha Witebsky - July 30, 2002